POSSIBILITIES FOR DEPLOYMENT OF SMALL MODULAR REACTORS   
IN SLOVENIA

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**Abstract**

Slovenia is a nuclear country with its only NPP in operation since 1983 that in 2023 extended its operational lifetime for 20 years until 2043. A project for a new GEN III PWR is starting and according to plan it should begin its operation in 2037. In parallel, there are some other interesting options for investors in SMRs available in the country.

In 2023, the Slovenian Ministry of the Environment, Climate and Energy started preparation of a joint project with US Department of State for assessment of possibility to replace coal-fired power plants with electric energy production by SMRs. The Ministry organized a task group of possible investors into SMR projects and expanded the group with national grid provider and the regulator, the Slovenian Nuclear Safety Administration (SNSA). The task group will prepare the pre-feasibility study concerning possible deployment of SMRs in Slovenia. The task force will receive consultancy and technical help from prominent US energy consultant company. The role of the SNSA is to provide information on licensing processes and legislative requirements for SMRs, including assessment of site-specific characteristics such as design provisions for external hazards and functional requirements for SMR design and operation. This project is planned to be completed by mid-2025.

1. INTRODUCTION

Climate neutrality refers to achieving a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. Slovenia's commitment to this goal aligns with the European Union's Green Deal [1], which aims for the EU to become the first climate-neutral continent by 2050. Slovenia’s strategy involves reducing greenhouse gas emissions, increasing renewable energy use, and enhancing energy efficiency. Nuclear power is a significant component of Slovenia’s strategy to achieve climate neutrality. Currently, Slovenia operates a single nuclear power plant, the Krško Nuclear Power Plant, which it shares with Croatia. Commissioned in 1981, the Krško NPP has been a cornerstone of Slovenia's electricity generation. The plant generates approximately one-third of electricity production in Slovenia and plays a crucial role in ensuring a stable and reliable energy supply. Nuclear energy reduces dependence on fossil fuels, decreases greenhouse gas emissions, and provides a consistent and reliable source of electricity. Nuclear energy, with its low lifecycle carbon emissions, is considered a cleaner alternative to coal, oil, and natural gas. Also, nuclear power provides a stable and reliable source of energy, which is crucial for Slovenia's energy security. Unlike renewable sources such as wind and solar, nuclear power is not dependent on weather conditions and can operate continuously, providing a consistent supply of electricity.

There are plans to expand Slovenian nuclear capacity by constructing a new nuclear power unit. A project for a new GEN III PWR is being considered [2]. According to some projections it should begin its operation in 2037.

However, building a large nuclear power plant is not the only option for using nuclear energy. The concept of Small Modular Reactors (SMRs) gained worldwide attention. The SMRs represent a significant advancement in nuclear technology, offering a range of benefits over traditional large-scale nuclear reactors. The modular design of SMRs allows for factory fabrication and rigorous quality control before assembly on-site. This reduces the likelihood of construction-related issues that could compromise safety. The modular approach also enables the integration of advanced safety technologies that might be more challenging to implement in larger reactors. The SMRs offer several economic advantages that make them an attractive option for energy producers and investors. These benefits include lower capital costs, scalability and lower financial risk.

1. PROJECT PHOENIX

Project Phoenix [3] is a program designed to enable transition from coal-fired plants to SMRs. This initiative leverages nuclear energy to meet rising global energy demands while reducing environmental impact.

In response to an invitation from the US Embassy in Slovenia, the Ministry of the Environment, Climate, and Energy successfully applied [4] to participate in the Phoenix project in 2023. Slovenia was awarded consultancy and technical services financed by the project Phoenix. The Ministry organized a task group which currently consists from GEN energija, Šoštanj Thermal Power Plant, Holding Slovenske elektrarne, ELES, Jožef Stefan Institute and the Slovenian Nuclear Safety Administration (SNSA). The US part of the partnership consists of representatives of the Department of State (DoS) and consultant company Sargent & Lundy (S&L), a leading global energy services company, which was selected through a DoS tender to secure funds for providing Slovenian stakeholders with technical advisory services for the project evaluating possible transition from coal to nuclear energy.

The goal of the Phoenix project in Slovenia is to prepare a pre-feasibility study for the potential deployment of SMRs in Slovenia. Six candidate locations for deployment of SMRs were identified in Slovenia. The study will assess the suitability of identified sites and determine the feasibility of deploying a suitable SMR at these locations in the future. No specific site or technology will be selected for deployment. The study will collect pertinent information and conduct an initial pre-feasibility study to exclude unsuitable sites based on SMR technology requirements. The study will also highlight the main advantages and disadvantages of each site, as well as identify the key infrastructure developments necessary for SMR deployment. The results of the study will be informative only and without any final consequences.

1. CONTENTS OF THE PRE-FEASIBILITY STUDY

The pre-feasibility study will cover topics [5] relevant for deployment of SMRs in Slovenia. The first section will consider applicable laws, codes, standards and guides. This section will list all applicable IAEA standards utilized in the pre-feasibility study. It will also include a list of applicable Slovenian laws, codes, and standards for reference in siting a new nuclear station. The next section will analyse electrical system in Slovenia. The Slovenian electricity system will be described, its current production, and demand forecasts for the future will be given.

Various information about six potential sites will be collected and presented in another section. On this basis, and taking into account information about available SMR technologies, S&L will screen the suitability of using the technology at each site. The information to be collected about sites may include but are not limited to: existing site layout including marking site boundaries of owner-controlled area and marking nearby utilities, infrastructure, etc; transportation routes to each site including maximum available load size (weight/dimension); list of site infrastructure assets and their status; construction feasibility and site access; cooling water source; flooding characteristics; geotechnical and seismic conditions, electrical interconnection and transmission capacity; electrical backup power available in the area of a given site; needs of cogeneration at each site; environmental, social, and permitting considerations. Feasibility of sites will be evaluated based on the results of the risk assessment and will include findings that could affect the scope of site development, and/or complexity of the nuclear licensing process.

Identification of criteria for suitable SMR designs for Slovenian LWR shall be determined by S&L which will gather publicly available information of mature technologies. About ten Western SMR designs including LWR and advanced reactor technologies that have evidence of licensing possibility by 2024 will be chosen. Two micro-reactor technologies (<10 MWe) with potential to support research capabilities as well as power production will also be selected.

Licensing in Slovenia and worldwide will be given in another section. In this section an overview of other international approaches to the construction and operating licensing of SMRs will be presented. This will include the methodologies of international agencies, such as the US Nuclear Regulatory Commission, French Nuclear Safety Authority, UK Office for Nuclear Regulation, and IAEA general approach. Other countries of similar size to Slovenia will be considered for benchmarking. Also, a description of regulatory process in Slovenia including timelines and critical regulatory requirements for licensing of new nuclear builds will be given. The licensing process for the construction of a new nuclear plant in Slovenia is currently divided into four phases. The first step is the siting of a new nuclear installation, which is completed by the adoption of a Decree of National Spatial Plan. This process is managed by the minister responsible for spatial planning and includes a number of spatial planning authorities with their experts, who provide guidance for the siting of the new nuclear object. The SNSA is preparing Guidelines for the Siting of Nuclear Installations according to the IAEA standards. The SNSA is also one of the regulatory authorities in the environmental impact assessment process. The next step is obtaining a construction license. SNSA participates in the construction permit process. The last two steps are licensing of trial operation and operation. The SNSA plays a key role in these two processes. The S&L will provide list of opportunities for optimization of regulatory process in Slovenia.

In a section devoted to economic analysis, S&L will compile information to aid in a general analysis of the overnight cost, levelized cost of electricity, and economic benefits for a potential SMR facility construction and operations. This analysis will be based on the projected SMR facility electric generating capacity. The analysis will include estimates of Overnight Capital Cost (OCC), Operating Expenses (OPEX), and Levelized Cost of Electricity (LCOE) of a SMR of a given size based on publicly available information. This will be developed independently of any reactor, site, or vendor selection. The S&L will work with the DoS to identify available funding and financing options for new SMR deployment.

Working meetings between the Slovenian and the United States side are regularly held online or live. Work on the pre-feasibility study is in progress. The pre-feasibility study is expected to be finished by mid-2025.

1. CONCLUSIONS

Slovenia has accumulated experience in utilizing nuclear energy from operation of its existing Krško NPP. Currently, the country is considering the expansion of its nuclear capabilities. Reflecting the growing interest in SMRs both in Slovenia and globally, Slovenia will evaluate the possibility of implementing a suitable SMR by participation in the Phoenix Project. This initiative aims to accelerate the global transition to clean energy by conducting feasibility studies and providing technical support to replace coal-fired power plants with reliable and safe zero-carbon small modular reactor (SMR) nuclear energy facilities. A pre-feasibility study is being conducted to explore the potential deployment of SMR technology in Slovenia, with the study expected to be completed in 2025.

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